Shut in Pressure Test and Methods of Calculating Shut in Time in Fractured Low Permeable Oilfields Wells

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Abstract

After oil wells were fractured, Pressure restore well test data of low permeable oilfields cannot test the straight line segment of radial flow easily. This paper analyzes the bottom hole flow characteristics in the earlier period of pressure restore test in fractured wells. Earlier flow in bottom hole is fracture single direction flow. It constructs a method for calculating the time of closing wells and measuring pressure in fractured oil wells using earlier well data. The method has practical application value, which can guide production.

Keywords

Low-permeable Oilfields; Production Wells; Transient Test; Shut-in Time And Measuring

Introduction

The content of well test includes the well production, pressure, temperature, sample of oil, gas or water etc. Based on fluid mechanics in porous medium, well test is used to confirm the production capability of the well, the physical property of the strata, the production performance, the boundary situation and the connection relationship between oil-water-gas strata through the usage of measurement instrument in production well or injection well. Well test is of crucial importance in petroleum reservoir engineering.

The two parts task of well test consists of data acquisition and data interpretation. The former is well site test and its major task is to collect enough reliable test data. The later one is well test interpretation and its task is to summarize more reliable information about the strata by the analysis of obtained data. These two parts are closely interconnected and interdependent. To get reliable well test interpretation is the goal of well test; and the prerequisite is to get accurate well test data. As a matter of fact, the quality and the quantity of well test results are determined by the quality and the quantity of data acquisition and the methods of data interpretation. At present, the interpretation methods technology is progressing parallel with the data acquisition advancement. And both of their progression is interconnected.

At present, the start time for shut-in pressure survey of oil well is based on the point where semilogstraightline occurred, which is also called mid-term section starting point or radial flow starting point. There are various judging criteria [1~5,10].Generally, the effective length in semilog radial flow straightline section for well test analysis should be less than two-thirds of log period. However, because wells start production after being fractured, the shut-in time for different wells are different, some buildup curves could not show boundary response to reflect true formation flow performance. Aiming at this problem, this paper proposed a new method to determine the effective shut-in time to reflect afterflow section, radial flow section and boundary response based on modern well testing theory and practical testing data in Changqing oilfield. This method could effectively reduce unnecessary testing time and increase effective testing time, which is useful for reference.

Background for Shutin Pressure Survey

Chang 2 reservoir in Sai 39 well area, ChangqingSuijing oilfield is low permeability reservoir. Well testing is an important method to evaluate formation dynamic performance. Transient test were applied in this area. According to the buildup test data, there were 23 sets of data in 19 wells showed constant pressure response, 31 sets of data in 23 wells showed no-mobile boundaries. No faults were found in this area and the no-mobile boundaries

were probably caused by lithological change or oil water interface around injection front.

Based on dynamic response, there were injection wells with no-mobile boundaries. The first time analysis result of injection well Lu 39-18 showed the existence of 2 no-mobile boundaries and the Lu 39-17 well on the west did not show effectual response. The second time analysis result still showed the existence of 2 no-mobile boundaries. Although the Lu 39-17 well on the west showed effectual response because fluid production, oil production and working fluid level all increased and water cut decreased. This effect should be caused by Lu 39-16 because the injection rate of Lu 39-18 decreased from 35m^3/d to 20m^3/d while the injection rate of Lu 39-16 stayed in 40m^3/d. Lu 39-19 on the east did not show any effectual response.

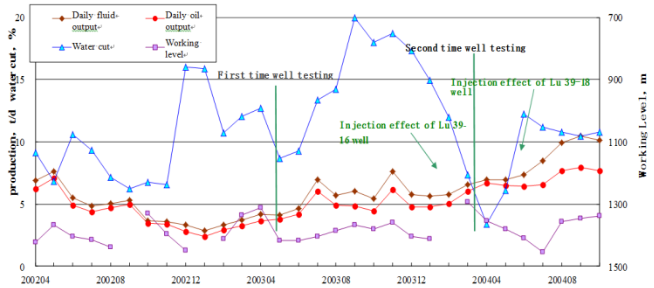

FIG.1 PRODUCING PERFORMANCE LU 39-17

But according to the recent dynamic response of Lu 39-17,there were effectual evidence that fluid production, oil production and working fluid level all increased and water cut decreased, the injection rate of Lu 39-16 stayed in 40m^3/d and the injection rate of Lu 39-18 sharply increased from 20m^3/d to 40m^3/d, the cumulative injection were close to 2.0×10^4m^3,which might be caused by Lu 39-18.It shows that although perforation section did not coincide, there were still some hydrodynamic relations because there were not stable mud layer for insulation. When the injection rate was big enough or changed, the adjacent wells could be stimulated. So the no-mobile interface might be influenced by injection front. It is necessary to have more research on this topic.

Theoretical Model

Radial flow must be reached to obtain formation dynamic data for fractured wells, besides, the time for pressure to reach boundary should be considered.

For fractured wells, radial flow starting time correlates with fracture conductivity. According to empirical equation proposed in the paper: Oil and Gas Well Test Data Interpretation write by Ding Gui-ming[3,6], the equation for calculating radial flow is:

$$t_{Dbs} = 5\exp[-0.5(k_{\mathrm{fd}} \cdot W_{\mathrm{fd}})^{-0.6}] \quad (1)$$

$k_{fd} \cdot W_{fd}$ ——fracture conductivity, $10^{-3}\mu m^2 \cdot m$;

t_{Dbs} ——radial flow starting time, h.

According to the empirical equation proposed in the paper: Feasibility of analysis for shortening test time of low permeability reservoirs published in Petroleum Exploration and development[7], is the starting point where radial flow is reached:

$$t_{\mathrm{bs}} = \frac{t_{\mathrm{Dbs}}\phi \cdot C_{\mathrm{t}} \cdot X_{\mathrm{f}}^{\ 2}}{3.6k}[(1-f_{\mathrm{w}})\mu_{\mathrm{o}} + f_{\mathrm{w}} \cdot \mu_{\mathrm{w}}] \quad (2)$$

X_f ——fracture half length, m;

f_w ——water cut,%;

k ——permeability,$10^{-3}\mu m^2$;

C_{t} ——total compressibility,MPa^{-1};

ϕ ——porosity,%;

μ_{o}, μ_{w} ——viscosity of oil and water, mPa • s.

For fractured wells, it is necessary to prolong buildup period to obtain qualified data. The buildup process was quite slow due to low pressure and low permeability. So the wellbore storage must be considered and the flowing time should be extended. According to the statistic of 54 sets of data in 42 wells, when the flowing time was three times the radial flow starting time, the error for interpreting formation parameter and pressure would be smaller, and it will be more accurate to judge boundary type.

Tripled radial flow starting time:

$$t_{\mathrm{bs}}' = 3t_{\mathrm{bs}} \quad (3)$$

Effective wellbore radius:

$$r_{we} = r_w^{-s} \quad (4)$$

In the equation: s ——skin factor;

r_w ——wellbore radius, m.

Applications

The average skin factor obtained from transient test for Lu 1-16,Lu 38-29,Lu 43-23 and Lu 42-15 wells in Chang 2 reservoir, Sai 39 well section, ChangqingSuijing oilfield is -4.3175.Combine skin factor with wellbore radius 0.062m, we can get effective wellbore radius r_{we}=4.65m.

Generally, facture half length in low permeability reservoir is 58.52m.Substitute it into effective wellbore radius equation r_{we}/x_f=0.07946, refer to the effective wellbore radius--finite conductivity vertical fracture relation schema[8~9].

$$k_{fd} \cdot W_{fd} = 0.29 \tag{5}$$

In the equation: k_{fd} ——permeability,10-3μm2;

W_{fd} ——width of fracture, m.

Substitute X_f=58.52m, ϕ=15.84%, C_t=17.57 1/MPa, μ_o=4.34mPa·s, μ_w=0.6575mPa·s, f_w=48.23% into equation (1),(2)and(3),we can obtain the flowing time that is three times the radial flow starting time(Table 1),we can see that the flowing time increases as the formation permeability decreases.

TABLE 1 THREE TIMES THE RADIAL FLOW STARTING TIME

K,10⁻³μm²	3	4	6	10	15	20
t_{bs}',d	50	37	25	15	9.9	7.4
K,10⁻³μm²	25	30	40	50	60	
t_{bs}',d	5.9	4.9	3.73	3	2.5	

Using Horner method, we can get radial flow starting time for Lu 39-17 and other 5 wells, the results are listed in table 2 and the Horner curve are Fig. 2.

TABLE 2 HORNER INTERPRETATION RESULT FOR TRANSIENT TEST

Well	Lu 39-17	Lu 41-16	Lu 45-21	Lu 38-29	Tian 128	Lu 42-15	Conclusion
Radial flow starting time, d	0.64	1.73	4.76	8.5	8.35	7.54	
Tripled radial flow starting time, d	1.9	5.2	14.3	25.5	25.0	22.6	
Boundary response starting point, d	3.9	6.9	8.9				
Test end time, d	24.0	22.6	15.7	15.0	13.0	14.8	25.0
Permeability,10⁻³μm²	45.44	27.42	9.93	6.63	6.13	6.76	6.0
Boundary type	Constant pressure	Constant pressure	Nonmobile	Not occured	Not occured	Not occured	Boundary occured

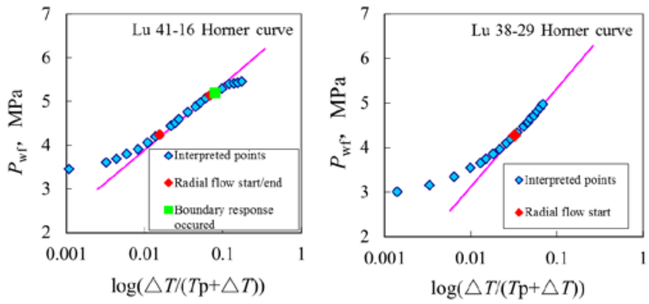

FIG. 2 LU41-16 AND LU 38-29 HORNER CURVE

From Table 2, it is easy to see that the test end time of Tian 128, Lu38-29 and Lu 42-25 are all shorter than tripled radial flow starting time, so Horner curve does not show boundary response, in comparison, test end time of Lu 39-17, Lu 41-16 and Lu 45-21 are all longer than tripled radial flow starting time, so we can determine boundary type from boundary response.

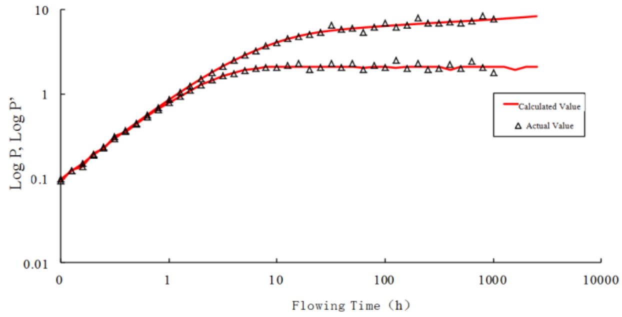

FIG. 3 LU38-29 UNREACHED BOUNDARY PRESSURE CURVE ANALOG

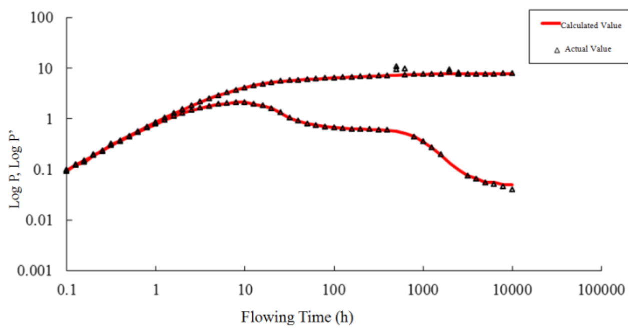

FIG. 4 LU 41-16 SINGLE BOUNDARY PRESSURE CURVE ANALOG

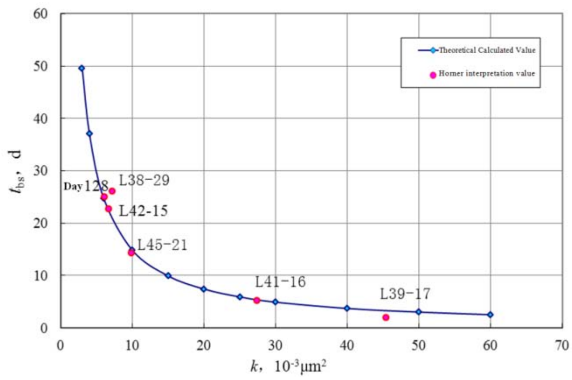

FIG. 5 TRIPLED RADIAL FLOW STARTING TIME—PERMEABILITY RELATION

According to boundary response, the test end time of Lu 38-29 is short that boundary response could not be observed (see Fig. 3). But Lu 41-16 reached radial flow period and we can observe boundary response (see Fig. 4).

It is easy to obtain tripled radial flow starting time—effective permeability relation scheme based on tripled radial flow starting time theoretical calculation equation (Table 1) and Horner interpretation result for transient test (Table 2).The results obtained from theoretical calculation equation and Horner interpretation are very close(see Fig.5).

So if we know effective permeability of certain formation, we can refer to the theoretical curve to obtain shut-in time for buildup test.

Conclusions

Conventional shut-in time could not obtain radial flow straightline section in low permeability wells so it's not suitable for calculating reliable formation pressure. This paper proposed an empirical method to calculate buildup test flowing time in low permeability reservoirs with smaller error and to determine the boundary type as well based on the data and the results provided above,. It could effectively save shut-in time to increase production.

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